

Wind Load Predictions for the 64-meter-diameter Antenna

M. S. Katow and H. D. McGinness
DSIF Engineering Section

Analytically computed predictions of the performance of the 64-m-diameter antenna in the wind environment have been uncertain because (1) The final design change in the porosity of the paraboloid markedly altered the similarity between the prototype and the wind tunnel models used at the preliminary design period and (2) the force values computed from static pressure taps in porous plates were doubtful. This report describes an effort to establish a correlation factor between the analytical model and the prototype using as a primary basis the field-measured azimuth torques of the 64-m antenna. A tentative conclusion is made that the maximum azimuth torque at 130-deg yaw angle computed from the static pressure taps of wind tunnel models using a full 50% reduction in forces to account for the 50% porosity must be increased 40%.

I. Introduction

The wind tunnel tests (Ref. 1) of the complete model of the 64-m-diameter antenna were based on the paraboloidal surface with 25% porosity in the outer 25% radius and azimuth/elevation axes located $0.142 \times$ diameter aft of the vertex. Owing to efforts to reduce costs, the final surface was built with 50% porosity in the outer 50% radius and the axes were moved to $0.126 \times$ diameter aft of the vertex.

During the final design period the aerodynamicists from the manufacturer (Rohr) and JPL generated pressure difference coefficient curves (Fig. 1) to reflect the design configuration similar to curves from the wind tunnel tests on paraboloidal dishes (Ref. 2). Figure 2 shows the locations of static pressure taps. The pressures derived from these curves were then used in the structural computing analysis on a conservative basis, with no allowance made for the porosity of the paraboloid at the outer 50% radius of the surface.

With the primary goal of verifying the correlations of azimuth torques between model and the prototype with different Reynolds numbers, the azimuth gearbox arms of the 64-m antenna were instrumented with strain gages. The first effort using solid-state strain gages was reported in Ref. 3. The second effort using normal strain gages, after some frustrating waiting periods for high winds corresponding to available time, has produced two sets of torque data used in this reporting. The details of the instrumentation, including the calibration means, will be made in a later reporting.

To improve the accuracy of the determination of wind speed, the oscillograph records of the wind speeds recorded in 1967 (Ref. 4) on the 92-m wind tower were recovered, and the wind speed at the antenna's centerline was established as a function of the air speed recordings at a height of 15.8 m for a nominal 9-m/s velocity.

The correlating efforts were directed at the maximum azimuth torque case at approximately 130 deg yaw angle. This condition produces the greatest uneven pressure differences on the surface panels, which results in the largest distortion rms on the paraboloid.

II. Field Torque Test Results

The sideview of the vertical locations of the wind speed indicators with respect to the 64-m antenna is shown in Fig. 2. The oscillograph records were input to the French curve subroutine available in the Fortran V library, and the best fitted curves for the three heights are shown in Fig. 3. As a sample, the actual oscillogram record is reproduced in Fig. 4 for the 15.8-m-height speed. Then based on the differences between the 15.8- and 46.4-m heights, it was determined that the yaw moment coefficients computed from the field tests should be decreased by 0.8 factor when the wind speed is measured at a 15.3-m (50-ft) height.

The yaw moment coefficients reduced from field tests are shown plotted in Fig. 5. The best fit curve by the "French curve" subroutine is shown by the solid line. Compared to the predicted curve from the wind tunnel data, its values are lower. In the fitting procedure, breakpoints were added to constrain the fitting of individual cubic equations between them. They were selected at the same yaw angle where inflections occurred in the typical torque coefficient curves (Ref. 1). Two additional constraints were added: (1) the curve was constrained to pass through zero values at 0 and 180 deg yaw angles, and

(2) the second derivatives must be continuous at the breakpoints.

III. Pressure Difference Coefficients

The pressure differential coefficients for solid and 50%-porous-throughout thin paraboloid dishes were available from Ref. 1 for yaw angles limited to 30-deg intervals. The locations of the pressure taps are shown in Fig. 2. With more pressure points necessary for the structural analysis, interpolating curves were generated (Fig. 6) based on the faired curves of Fig. 1. This fairing was done to simplify the structural analysis. With all these faired curves starting from zero at the center, the same pressure data divided by 2 is usable for the symmetric and the antisymmetric structural half-model of the antenna for the crosswind-type wind loading.

The resulting pressure difference coefficients were used to compute the actual forces on the workpoints of the reflector structure using the dynamic pressure of the desired wind speed. Then, these forces multiplied by their individual lever arms to the azimuth axis were summed to output the azimuth torque resulting from the wind loads on the paraboloid.

In the above calculations, the pressure difference coefficients for the outer 50% radius were divided by 2 to account for the porosity.

IV. Correlation Results

First, all azimuth torque coefficients from the wind tunnel test results (Refs. 1 and 5) were corrected to reflect the prototype's distance from the vertex of the paraboloid to the azimuth/elevation axes of $0.126 \times \text{diameter}$.

The azimuth torque coefficient at 130 deg yaw angle for the complete model (Ref. 1) is shown by bar 2 of Fig. 7. Its value is lower by 0.013 than for the dish alone of equal porosity, which is shown by bar 1. The yaw torque coefficient from the field torque test (Fig. 5) is shown by bar 4. To obtain the dish-alone torque value, it is aerodynamically logical to add to the complete model coefficient the same difference in coefficients "A" as defined by the wind tunnel tests described above. The result is bar 5 for the 50% porosity in the outer 50% radius for the dish-alone configuration. This torque of bar 5 is larger by 40% than the torque computed by integrating the interpolated pressures computed from static pressure taps.

A basis for this disagreement may be backed by the aerodynamic property of porous plates instrumented by surface static pressure taps. References 1 and 5 as well as a memorandum from R. W. Weaver (Aerophysics Section) indicate that, as the angle of incidence of the wind direction to the surface of the plate increased from the normal, the ratio of the pressure force to the computed force from the static pressure difference increased. In other words, allowing the full 50% effective porosity may only be correct for the pressure taps on the 15 deg = θ radial line of Fig. 2. For 45 deg and larger angles, the effective porosity must be decreased. From this torque match, the wind pressure forces may be developed for use in computing the distortion rms from the wind load at 130 deg yaw angle.

At this time, only two sets of data from the field torque tests are available. The first set was obtained when the wind velocity at the 15.3-m (50 ft) height varied from 6.7 m/s (15 mph) to 15.7 m/s (22 mph). From previous

attempts, since it was determined that this lower velocity produced inconsistent results, this may have accounted for the wide scatter of data.

The second set was obtained during an Apollo track at an elevation angle of 32 deg, where the wind velocity was about 18 m/s (40 mph), and the results are shown as circled points. These data points are considered to be more accurate because of the higher moments resulting in larger strain gage outputs. These moment values are lower than the predicted curve.

As corroborating data, the 50%-porous-throughout, dish-alone yaw moment coefficient from wind tests was calculated for a moment center of 0.126 aft of the vertex using values from Fig. 14 of Ref. 5; the resulting coefficient of 0.128 is shown by bar 7 of Fig. 6. Decreasing this value with the correlation ratio of the model/prototype of this article would lower it below the height of bar 5 where it logically belongs.

References

1. Blaylock, Robert B., "Aerodynamic Coefficients for a Paraboloidal-Reflector Directional Antenna Proposed for a JPL Advanced Antenna System," IM CP-6 (an internal document), Jet Propulsion Laboratory, Pasadena, Calif., May 1, 1964.
2. Fox, Norman, "Load Distributions on the Surface of Paraboloidal Reflector Antennas," IM CP-4 (an internal document), Jet Propulsion Laboratory, Pasadena, Calif., July 1962.
3. McGinnes, Houston, "Measurement of Wind Torque," in *The Deep Space Network*, Space Programs Summary 37-52, Vol. II, pp. 97-105, Jet Propulsion Laboratory, Pasadena, Calif., July 31, 1968.
4. Katow, M. S., Van Keuren, W. W., and Newsted, M. G., "Study of Environmental Wind Conditions at DSS-14," in *The Deep Space Network*, Space Programs Summary 37-49, Vol. II, pp. 152-153, Jet Propulsion Laboratory, Pasadena, Calif., Jan. 31, 1968.
5. Fox, Norman L., and Dayman, Bain, Jr., "Preliminary Report on Paraboloidal Reflector Antenna Wind Tunnel Tests," IM CP-3 (an internal document), Jet Propulsion Laboratory, Pasadena, Calif., Feb. 28, 1962.

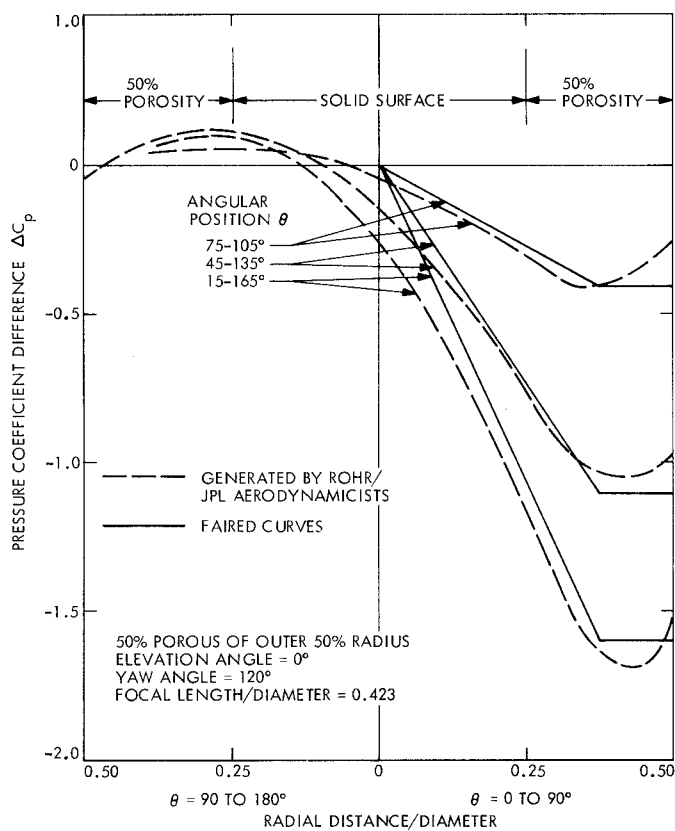


Fig. 1. Pressure coefficient difference across a thin paraboloidal dish surface

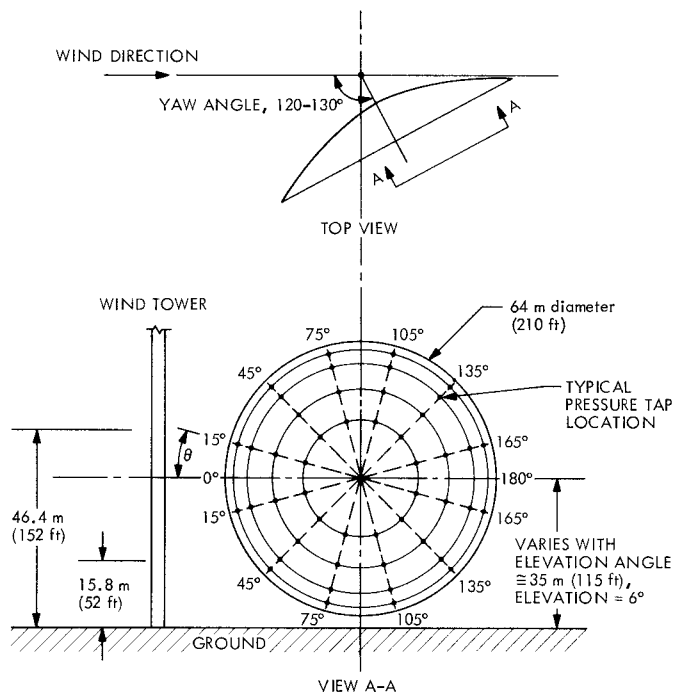


Fig. 2. Pressure tap locations, 64-meter-diameter antenna

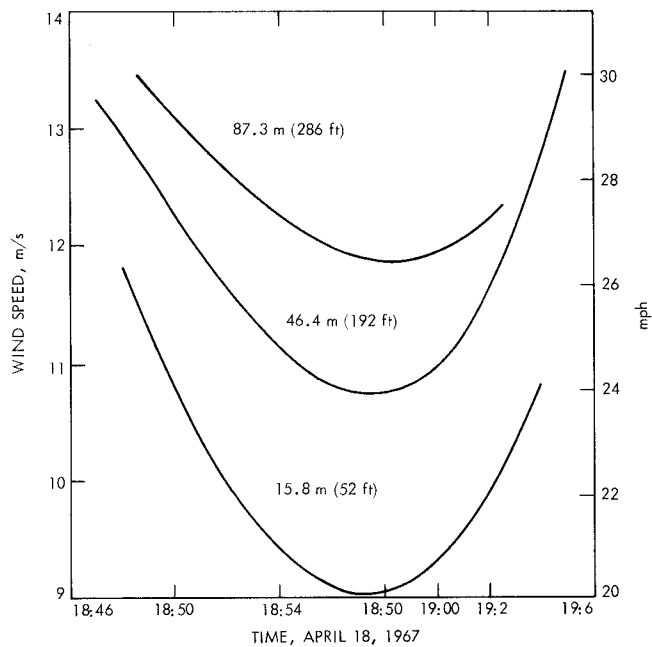


Fig. 3. Wind speed vs height

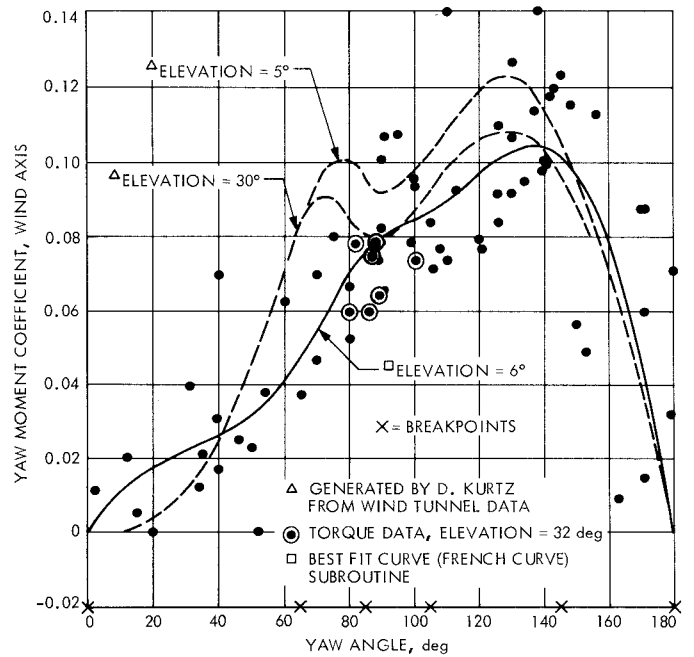


Fig. 5. Yaw moment coefficient, 64-meter-diameter antenna

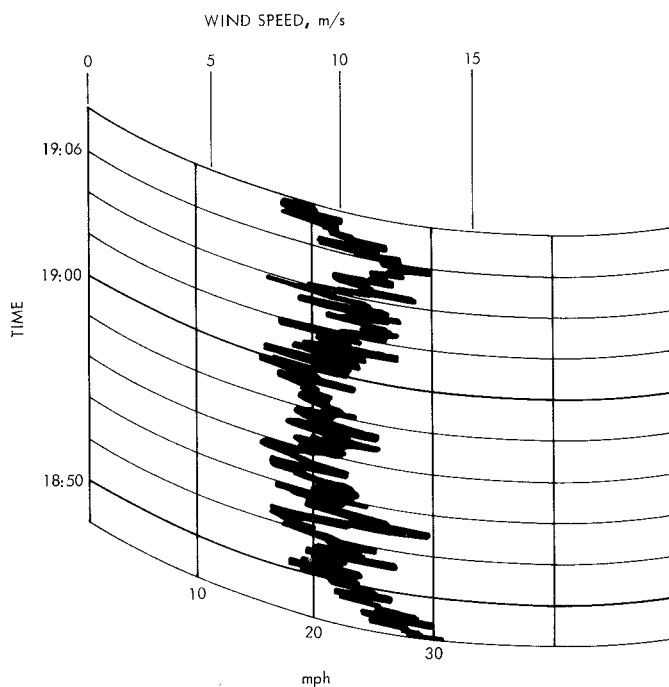


Fig. 4. Oscillogram record

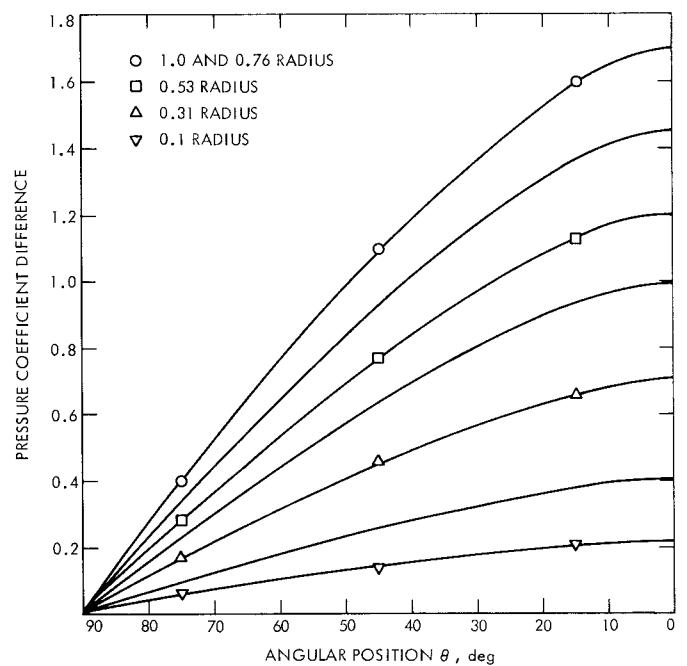
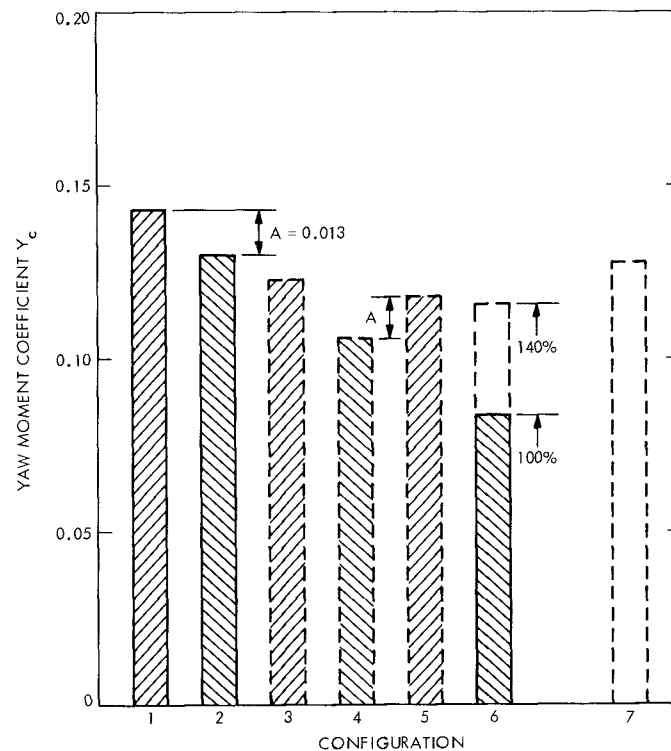


Fig. 6. Pressure coefficient difference—interpolated values



MODEL	DESCRIPTION	DATA SOURCE
(1) DISH ALONE	25% POROUS 25% OF OUTER RADIUS, $F/D = 0.33$, MOMENT CENTER = 0.126 AFT OF VERTEX	WIND TUNNEL TEST
(2) COMPLETE ANTENNA	SAME AS (1)	WIND TUNNEL TEST
(3) COMPLETE ANTENNA	50% POROUS 50% OF OUTER RADIUS, $F/D = 0.42$, MOMENT CENTER = 0.126 AFT OF VERTEX	AERODYNAMICIST GENERATED
(4) COMPLETE ANTENNA	SAME AS (3)	WIND TORQUE TEST
(5) DISH ALONE	SAME AS (3)	A = ADDED
(6) DISH ALONE	SAME AS (3)	INTEGRATED PRESSURES
(7) DISH ALONE	50% POROUS THROUGHOUT	WIND TUNNEL TEST

Fig. 7. Yaw moment coefficients, 64-meter-diameter antenna—6-deg elevation angle, 130-deg yaw angle